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A COGNITIVE APPROACH TO INSTRUCTIONAL TECHNIQUES AND  
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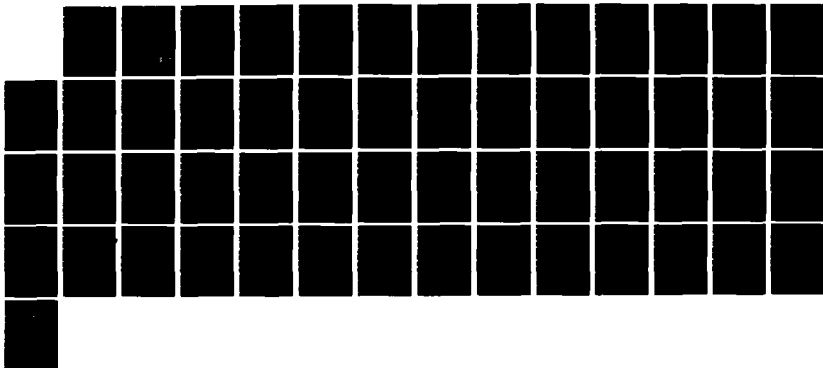
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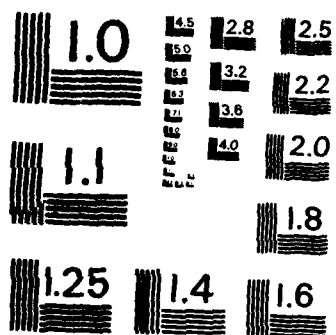
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## CHAPTER I: INTRODUCTION

We see, today, that cartographic instruction consists of teaching map notation and teaching about the elements that can be combined to form a map. For instance, consider the following map making topics most extensively treated in the common cartographic text, Elements of Cartography by Robinson, Sale, and Morrison:

- 1) The Spheroid, Coordinate Systems, and Map Scale
- 2) Map Projections and Plane Coordinates
- 3) Data Ordering, Representation, and Compilation
- 4) Processing Cartographic Data
- 5) Cartographic Generalization
- 6) Symbolization: Qualitative, etc., etc.

Clearly, the above are all topics which generally concern the cartographer. We also find that most cartographic research is oriented toward specific questions about the above subjects, thus making the cartographer's conceptualization of his craft tangible. The cartographer and his maps are not an isolated system, however. Indeed, maps are created to be utilized by humans in the tasks of way finding, understanding the economic, political, social, and historical relationships that connect people and places of different spatial regions, and others.

The current emphasis, in cartography, on these topics definitely generates good cartographic skills in map makers.

A Cognitive Approach to  
Instructional Techniques and Color Selection  
in Mapping

by

THOMAS M. PERRY

A thesis submitted in partial fulfillment  
of the requirements for the degree of

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## CHAPTER I: INTRODUCTION

We see, today, that cartographic instruction consists of teaching map notation and teaching about the elements that can be combined to form a map. For instance, consider the following map making topics most extensively treated in the common cartographic text, Elements of Cartography by Robinson, Sale, and Morrison:

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Clearly, the above are all topics which generally concern the cartographer. We also find that most cartographic research is oriented toward specific questions about the above subjects, thus making the cartographer's conceptualization of his craft tangible. The cartographer and his maps are not an isolated system, however. Indeed, maps are created to be utilized by humans in the tasks of way finding, understanding the economic, political, social, and historical relationships that connect people and places of different spatial regions, and others.

The current emphasis, in cartography, on these topics definitely generates good cartographic skills in map makers.

However, there are a preponderance of people, particularly laymen, who are in need of remedial training in map conceptualization, utilization, and reading skills. These are the people for whom maps are most often intended. The problem, then, is not one of changing, or even discarding current thought and theory in cartographic instruction and research but is how to incorporate a change that includes educating laymen to the fundamental concepts of "mapping." It is "mapping," the active mental process of thinking about the representation of space, or characteristics which can be ascribed to it, or the arrangement of objects in it, which we are concerned that laymen have knowledge or understanding.

At this point in time there are relatively few methods of instruction in "cartography" that afford such understanding to laymen. However, there are "methods" of teaching in language and music that might be applicable. The purpose, then, of this exposition shall be to first, provide an overview of the state of current cartographic focus by reviewing some recent research in the field. Research in cartography is directly reflective of the type of thought and concerns that pervade the field at any particular time. This, in turn, is naturally reflected in the type of instruction given in the field. Research and instruction tend not to be mutually exclusive. Then it is the characteristics of the instruction obtained

which is of general interest.

This leads to the second purpose of this paper which is to show how the above mentioned approaches to language and music can be applied to cartography so that current emphasis in instruction and research (cartographic approach) is not one-sided or deficient. The teaching method (with its emphasis on "mapping") could be applied to young children so that a more holistic relationship between cartographers and laymen (map percipients) can be fostered and so that the need for remedial training in map use and perception in laymen becomes obsolete.

## CHAPTER II: PSYCHOPHYSICAL VERSUS COGNITIVE DESIGN IN CARTOGRAPHIC RESEARCH AND INSTRUCTION

The form of this discourse will be that of a position paper. Several examples of cartographic theory and research of the last five to ten years will be examined and suggestions made to include a new instructional technique that will enhance them. Before proceeding further, though, it is necessary to describe the approach to research and instruction currently espoused and to describe its foundations.

Cartographic instructional technique is deeply rooted in psychophysical research and analytical-rational thinking. Evidence of this is not hard to find. All one has to do is pick up most any cartographic journal or proceedings paper. The values of society propel us forward into an age that is highly technical and specialized. Because of technology, training and education in "scientific" areas have been tailored more to fit those specializations. Even our formal education system has devoted much of its effort to teaching a highly structured and rational approach to cartography, as implied in the introduction.

Current theory focuses on the compilation, design, and production of maps. This, however, is only one aspect of cartography, as art or science. Current carto-

graphic theory relies heavily on communication models to depict the cartographic process. That is, they focus on 1) the need for or conception of a map in the map maker's mind, 2) his thought process in creating the map, 3) the physical production of his idea, and 4) the communication of this idea to a percipient. Practice, then, generally relates the compilation, design, and production of maps to the map maker exclusively.

On the other hand, cartographic research is devoted to psychological studies about the way humans react to maps. This is basically a behavioral approach in which the results are used to aid the map maker in creating "better" and more "efficient" maps. Gilmartin (1981, p.10) identifies two components of the behavioral approach; the cognitive and the psychophysical. Psychophysics is basically concerned with how living organisms respond to stimuli in the environment. Much research, then, is concerned with establishing a quantitative relationship, which is a matter of magnitude, between the physical stimulus and the perceptual response of the percipient. The degree of magnitude of the relationship is usually accepted as a power function by researchers. It is

stated that the subjective magnitude of a stimulus is equal to the magnitude of its physical response raised to some power.

Cognition, like psychophysics, also encompasses perceptual responses. However, Gilmartin (1981, p.11) professes, cognition can be described as the process by which living organisms become aware of their environment or aware of some object. This process includes such things as perception, discovery, recognition, imagining, judging, memorizing, learning, and speech. Often times, other terms such as sensation, imagery, retention, recall, problem-solving, and thinking are referred to and included in a definition of cognition.

Most perceptual experiments are neither purely psychophysical or purely cognitive, but a mixture of both. More emphasis should be placed on the cognitive, though, because it is the other half of psychological research. Psychophysical inquiry is dominant at present. In the cognitive view people are seen as active organisms that filter information, act selectively, organize experience, and create, instead of viewing them as passive receivers and storers of information. Gilmartin (1981, p.18) continues:

This is not to say that cartographers cannot conduct a cognitive (or psychophysical) study using maps. What makes

the study either cognitive or psycho-physical is not a unique methodology or independent perceptual system associated with the research, but the questions asked and the goals sought.

This is precisely the crux of the matter when it comes to cartographic research. We have too often tried to base our understanding on stimulus-response models of map perception. Our understanding and, thenceforth, our actions based on that understanding should start to focus more on cognitive and intuitive methods of approach.

Gilmartin is not the only academician that believes that the questions asked and the goals sought in our study and research in cartography influence our own perceptions of the subject. Shortridge (1980) conducted an experiment where specific instructions in the psycho-physical test setting were influential upon test results. In this test, subjects were asked to differentiate between two solid black dots on the map. They were given one of a set of three instructions. The first instruction forced the subject to choose one or the other of the dots as larger. The second instruction allowed a response indicating that the dots were the same size. The third instruction led the subject to believe that some answers should be "Same." The results indicated that a larger

physical difference in dot size was necessary, with each successive instruction, before the subjects recognized a difference. Shortridge then comments that the results are in accordance with signal detection theory, which predicts that a subject's responses are determined by his decision criterion. The conclusion is drawn that test instructions should attempt to elicit a decision criterion similar to that used during actual map reading. This is the type of research and learning that the author will present in a clearer fashion shortly. It can be said, though, that the approach has to do with cognition. It has to do with what is going on in the "black box." It has to do with human functioning and life itself.

In another article Shortridge (1982) poses the question, "Stimulus processing models from psychology: can we use them in cartography?". The conclusion is yes, we can use psychological stimulus processing models in cartography, but a more fundamental need for inquiry is also addressed in her exposition. It is suggested that cartographers do not share with cognitive psychologists the emphasis on what is happening inside the black box. Shortridge explains that psychologists are concerned with processing behavior and the stimulus is viewed only as an instigator of behavior. Cartographers have traditionally skipped several steps in an information



processing model because emphasis has been placed on stimulus-response relationships. This emphasis agrees quite nicely with the definition of psychophysical inquiry and investigation. The question that must be kept in mind is, "What about all the other myriad relationships that a subject or map percipient may have with his environment and the map?". Certainly, the physical, emotional, or mental response is only the result of the functioning of all these relationships upon and within the percipient. This is where a cognitive, intuitive, and holistic theory and approach to instruction come in. Before delving into such an approach let us further explore some of the theories, approaches, and research activities of cartographers in today's world.

Lloyd and Yehl (1979, p.150) have done research about orderly maps and map communication. They indicate that communication should be considered from a cartographer's and a map reader's point of view. How do they propose this be done? They suggest that cartographers be familiar with and aware of the needs and abilities of map readers. Then the presumption is made that map readers assume a particular order of importance among the various map elements, e.g., title, legend, etc., and moreover, that corresponding visual hierarchy of letter sizes on the map reinforces

that importance. The experimenters go on to test their suppositions and conclude, indeed, that coordinating letter sizes with the importance of the map elements does provide a more orderly map for map readers. An orderly map means that the graphic elements within the map design are arranged so that there is a clear visual impression of what is meaningful and an order to the components that make up the individual parts of the map (Lloyd and Yehl, 1979, p.149).

Lloyd and Yehl obviously established a good criterion for map design, i.e. that a map be orderly, as defined above. However, they did little in discovering the why behind their results. Their experiment was one of recall for their subjects. An investigation into the relationships between memory and hierarchical style might have illustrated a fundamental link between the why a certain map object is recalled and the best way of creating the object to facilitate that recall. The approach to this problem most likely lies within the realm of cognitive-intuitive learning and research (refer to Chapter III).

In 1985 Castner and Eastman (p.30) performed a psychophysical study on eye-movement parameters and perceived map complexity. A key concept utilized was imageability - "that visual quality of a map that an observer of a map area generates in his mind and retains during map reading and landscape interpretation." Imageability is directly related to perceived-complexity judgments

about a map. In other words, "perceived-complexity judgments would be based on subjects' ability to form and use a 'good' cognitive model of the surface in question" (Castner and Eastman, 1985). When it came to measuring perceived-complexity in the judgments of their subjects, the experimenters produced a test that only evaluated on a psychophysical level. That is, subjects were timed in their search for assigned targets.

The timing took the form of measuring fixation durations of the aforementioned targets. Also, interfixation distances (distances, denoted by degrees of arc, between fixations) were measured. Without going into too many of the details it was found that fixations of around 250-300 msec were characterized, after Buswell (1935), as general survey fixations. "This corresponds to the speed of the basic process of internalization of any iconic representation of fixated features" (Haber, 1971). These fixations generally represent reading and picture viewing. Fixations of 300-500 msec were correlated with perceived map complexity, and fixations of 600 msec and greater were characterized as going well beyond the stage of data acquisition (encoding visual stimuli, decoding their meaning). The eye remains stationary during this type of processing, and thus the fixations probably are indicative of higher-level integrations by the central processor.

These fixations then are "well removed from consideration of what is immediately before the eye" (Castner and Eastman, 1985, p.34).

It was also found that tests regarding interfixation distances were far from conclusive. No definitive statement was made on the subject.

It can be seen that the experimenters were definitely concerned with a cognitive approach to their area of study, evidenced by their use of the term imageability. It is unfortunate, though, that this concept was transformed into a psychophysical experiment. It seems that in these types of studies a psychophysical approach is chosen because of experimental constraints, the prime culprit being time. It seems logical that cognitive study involves longitudinal experimentation and learning. This is true because the cognitive view sees the human organism as an active seeker of knowledge and processor of information. It is over a period of time, then, that dynamic forces influence our mental imagery and cognitive processes. These are the types of studies that this author supports. However, such studies are deemed unpopular in a world where any specific technology could be revolutionized in a day. (Consider the application of computer graphics to cartography and the resulting controversies as an example). Let us take into account

further examples of current cartographic inquiry.

Peterson (1985) also begins with an attitude that cognition is important to the cartographic process. Then, through a series of logical ideas he comes to the conclusion that psychophysical investigation can thus describe the cognitive process in question. The line of reasoning goes like this:

... In the cognitive framework, the principal purpose of maps is communication of information in the form of images to a subject's previous knowledge structures. Fundamental to image formation is visual-pattern recognition, the mental integration and organization of a group of sensations into a meaningful whole. How effectively this process occurs depends on pattern quality, the measure of the quality of image information derived from a spatial display. (p.54).

There is no argument with the "correctness" of the above contention. There is only concern as to what is happening "between the lines." For instance, how are images communicated to a subject's previous knowledge structures? For that matter, how are previous knowledge

structures defined? How is image formation fundamental to visual-pattern recognition? How is visual-pattern quality related to the quality of image information derived from a spatial display?

The beauty of Peterson's reasoning is that it draws all of the other researchers' concerns about the cognitive aspects of their work into a concise package. We hear echoes of Shortridge's concern with information processing models, Lloyd and Yehls' derivation of meaning from visual hierarchies, and Castner and Eastmans' concept of imageability. All of these subjects, along with the questions posed formerly deal with cognitive processes. It is the analysis of them that allows us to begin to see the nature of relationships as between map percipient and 'mapping.' Once we comprehend that relationship, we are capable of instituting programs that will enhance it.

The enhancement of such relationships is of fundamental importance in the area of cartographic instruction. The reason is that "the relatively recent research emphasis upon the map reader has not yet overcome the tradition of using mapmaking as a paradigm for map reading...." (Olson, 1979, p.39). In trying to discover relationships between map percipient and mapping, we are inherently dealing with cognition. Then, "...our goal is discovery of the nature of what we have been doing all along," (Olson, 1979, p.40).

### CHAPTER III: AN ENHANCED INSTRUCTIONAL TECHNIQUE FOR CARTOGRAPHY

In this chapter we are concerned with an instructional method that could enhance the application, or use if you will, of the cartographic product, the map. To gain an appreciation for the usefulness of this method as a valid approach to map understanding, it is necessary to illuminate some of the underlying processes of human understanding in general. Once we realize how people understand something, in this case maps, we are capable of putting into effect programs which will promote that understanding in positive ways.

In this case we are particularly interested in developing an understanding of how a map percipient and a map product interact. The emphasis here is on interact because our focus is upon the mental activity (action) which is derived from an encounter with a cartographic product. Notice that mental processes are of primary concern because it is understanding which we wish to gain. That is why emphasis will not be placed on how a map percipient reacts to a visual stimulus. This kind of emphasis does not provide us an understanding of what happens mentally to a percipient when he encounters maps. It just affords an understanding of the physical reactions that a map causes in percipients. This, in turn, affords the generation of hypotheses for better

map creation, design, production, etc.

The goal here, then, is to foster an understanding of how spatial concepts are thought about and processed. We want to create a method of instruction that promotes the percipient's understanding of spatial concepts already in existence. The kind of understanding previously mentioned is one of how an organism reacts to a map, which is obtained by observation and exploration. The understanding we seek is the why. That is, when we are able to realize why a percipient understands a cartographic product the way he/she does, we will be able to develop an instructional method that magnifies and enhances that understanding.

At this time we do not have concrete reasons as to why people understand maps the way they do. In other words, their thought processing patterns regarding mapping are not readily available for our inspection. However, much research has been accomplished regarding the thought processes surrounding language activities. Therefore, it is our purpose to identify a link between natural language and mapping, which has its own semiotic language. Note well that it is not our intent to identify structural similarities between the two



systems, but to identify a thought process that may be common to the processing of information in each system. Understanding of similar thought processes, afforded to mapping by virtue of the research done in language, could definitely propel us forward in the creation of instructional programs that would provide understanding in mapping for the general public.

Fundamental to understanding is cognition. A great contribution to this area has been made by a developmental psychologist named Piaget. He postulates that there are two functional invariants that exist across the entire range of human development. They are hierarchical organization of cognitive structures and the process of adaptation. Adaptation consists of accommodation (changes in the organism due to the state of the stimulus) and assimilation (changes in the stimulus due to actions of the organism). Cognitive growth occurs with the equilibrations between the two states. Also, each state must be derived inevitably and logically from that which proceeds it.

Petchenik (1979, p.9) states:

What concerns us here is the conclusion  
that all cognitive development is gradual,  
must be gradual, with each advance  
tightly related to the previous one.  
What finally emerges as perceptible

qualitative differences or stages results from a long series of tiny stepwise developments, with subsequent reorganization of hierarchical structures.

If it is necessary for cognitive growth to be attained for understanding to take place, we must likewise be concerned with the meaning of cognition. Many hypothetical aspects of cognition are described by a single word: sensation, perception, imagery, retention, recall, problem-solving, and thinking. However, it is cognition in the sense of a process that we are concerned about. The reason is that we are concerned with mental process rather than external behavior. Process is not observable directly.

What cognitive process are we concerned with here, then? C. Grant Head (1984, pp.1-19) describes what is involved in "The Map as Natural Language: A Paradigm For Understanding." He uses a processing model borrowed from Dominic Massaro (University of Wisconsin). Then he applies the model to the reading of printed text. Finally, an analogy to map reading is considered.

The Massaro model consists of structural and process components. Structures include the preperceptual store (PPS), that holds all characteristics of the stimulus that are physiologically processed by the eye; short-

term memory (STM), the work place of the system; and long-term memory (LTM). PPS has a short retention time, but a large item capacity. STM is divided into synthesized visual memory and generated abstract memory in Massaro's model. LTM may have an unlimited capacity. These structures are utilized when the processes of the model are employed in reading text. The processes are feature detection, primary recognition, secondary recognition, and rehearsal and recoding. The result of the operation of these processes is meaning.

Head presents an application of the processes operating in the reading of printed text. We start reading at the upper left (culturally dependent) and follow the lines across the page. Information from foveal views (small oval views created as a result of the nature of our visual system) is deposited into preperceptual visual storage. Then, the eye jumps to another fixation (within a quarter of a second) and the deposition process begins all over again. Codes or algorithms then analyze the material in PPS for features that make contact with a meaningful package in LTM. These features may be angles, lines, dots, etc. that allow differentiation of letters in the primary recognition stage. Features are combined into a new item, the letter, which can be transferred into STM as an idealized letter creating a 'synthesized

visual percept.' The percept now takes up to  $7 \pm 2$  storage units in STM. Its creation occurred through an interaction of environmental data and LTM. There is no longer a one-to-one relationship with the physical stimulus because it is lost from PPS after a quarter of a second. A new set of programs in LTM are now applied to these percepts in synthesized visual memory (in STM). It is called secondary recognition and involves using orthographic, semantic, and syntactical rules to build syllables and words. It is an attempt to close off letters into a word and match it to a word in the lexicon of LTM. The word will be recognized if its perceptual code is the best match and its conceptual code is pertinent to the particular context. The words are then deposited in generated abstract memory (in STM) as meanings, not physical likenesses of words. As the store grows rehearsal and re-coding create meaning for phrases, which in turn combine meanings to form propositions (sentences). Each of these stages produce 'chunks.' A series of data is reduced to a new concept. This can be seen as an essential data reduction task. The chunks that we make of small items like features and letters is governed in part by the chunks for which we search, which is largely dependent on the orthographic, semantic, primary recognition, etc. rules we have learned. (Head, 1984, pp.3-5).

Head then likens the above example to that of 'reading' a map. He starts by explaining that there are no conventions for the spatial sequencing of features on a map like there are in printed text. However, an experienced map reader will likely start by locating himself relative to his particular task. Then the early stages of map reading begin. They utilize the same processes as similar stages in reading text. "The visual receptor system deposits information of one eye fixation into PPS, and within a quarter of a second, drawing on programmes (sic) in LTM, the features in PPS are analyzed for meaningful primary combinations and these percepts are transferred to synthesized visual memory in STM," (Head, 1984, p.6). The material momentarily available in PPS is somewhat like a photographic copy of the foveal view on the map. It is analyzed for features in a primary recognition stage, which is based on knowledge of what is significant. Narrow, linear, and brown features are recognized in combination as a contour line. The percept is then deposited in synthesized visual memory in STM. The whole process is repeated with the loss of material in PPS, which is being provided more material by a new fixation.

Once a minimum number, say three, of 'contour lines' reside in synthesized visual memory, secondary recognition can take place. Attempts to build a larger construct

using programs from LTM may then follow. A reader may acquire the notion of 'slope' by applying programs from LTM to the three contour lines. This is analogous to closing off the letter string into a 'word,' thus losing contributing percepts. Three contours have been replaced by one item, slope. We may say that the contours have become 'transparent.' Just as words can be built into phrases and phrases into propositions, a collection of associated slopes may be recognized as a drumlin. In each case contributing items may be recognized as a drumlin. In each case contributing items are replaced by a broader concept. We agree, though, that none of this can be done unless the reader brings programs (algorithms) with him to the map reading task. "Map reading, like all reading, then, is cognitive, and draws as much upon the reader as it does upon the marks on the face of the map." (Head, 1984, pp. 5, 6).

The above processing model presents a mechanistic depiction of how the cognitive link between language and mapping may be established. There has been no attempt to describe the actual mental activity that surrounds the stages of the processing model. Instead, a description of each stage furnishes us insight into the manner in which a map percipient may 'understand' (contemplate, comprehend) spatial aspects of a map. This answers the

question How. The next question that must be focused on is What. The connection between the programs that a reader brings with him to the map reading task and to cognitive development must be established. Remember that Head brought an experienced percipient to the map reading task.

The programs brought to a map reading task by a percipient fit into part of a cognitive cycle proposed by Ulric Neisser. The cycle has no particular beginning and continues indefinitely. Take for instance an object (stimulus). It modifies our plan for 'doing' (schema), which directs exploration. In exploration new objects are sampled, thus modifying schema, and so the cycle continues. The programs of our percipient are schemata which direct exploration, spurring the sampling of objects which modify the schemata. This cycle, then, is a model for human information processing.

"Fundamental to the concept of human information processing is the notion that information becomes available and moves through the human system towards cognition in pieces, over time." (Head, 1984, p.3). This concept (Piaget's) was referred to earlier in the paper. We notice that the information gathered in the above examples was processed over a period of time. As integration and synthesis proceeded meaning was generated. This occurred

through the data reduction task of chunking. The point of central focus is that meaning was generated over time from the application of the cognitive processes mentioned above. The acquisition of meaning accompanies and is embedded in cognitive development.

Barbara Bartz Petchenik (1979, p. 8) states that the difficult question of what maps mean and how they come to have meaning at all is emerging in cartography. In order to approach meaning we must have knowledge of the cognitive process by which the human being acquires or constructs meaning.

More and more, literature reinforces the assertion that meaning obtained through cognition takes on the practical form of what one might call practice. Consider again the cognitive cycle of Neisser. Meaningful constructs are attained when the data reduction process of chunking is applied to the repetitive object-schema-exploration cycle. The repetitive object-schema-exploration cycle may be termed practice. When accomplished through data reduction tasks and the cognitive cycle, practice generates meaning. It is practice which may include Piaget's idea of adaptation, and it is practice which affords the gradual stepwise cognitive development that finally emerges as perceptible differences or stages.



Let us consider an example of how meaning can be construed from a map (not focusing particularly on the mental process, but on Neisser's cyclical cognitive model, practice). Consider a soldier, for instance. His aim is to be able to read the terrain or landscape, but how is this ability acquired? "Learning map craft is like learning to ride a bicycle. You cannot learn from a book. You take a bicycle, with an experienced friend to guide, encourage, and assist, and you try...You take a map into the country, and you try, (War Office, 1961, p.2)," (Board, 1984, p. 90). "The 1973 edition of the manual merely says that 'mapcraft is a practical skill which must be learned by practice with a map on the ground, thus building experience and developing a feel for the map which should become instinctive' (p.3)," (Board, 1984, p.91).

There is a consensus that the mental construct of the terrain depends on the map reader's experience of the terrain in the field. Fairgrieve, a prominent British geographic educator, argued that mistakes were due to inaccurate imagination of the real world. These mistakes were traced to map use, "'to thinking of the map instead of the reality behind the map; to worshipping the symbol instead of the thing for which it stands'(1937, p.109)," (Board, 1984, p.90). "'A great deal of geography is learned by actually seeing things...., the more experience one has of seeing things, the more maps mean (writers

emphasis) and the less they are an obsession' (p.113)," (Board, 1984, p. 90). In teaching map reading Fairgrieve notes that children know much about their environment. We should start by translating this knowledge into map terms. Ultimately the terms "'must be not merely learned, but learned so well that they are scarcely noticed, while the ideas which they convey stand out prominently. The aim is to use a map as one uses a binocular, i.e., to look through it, not at it, and to be as little conscious of it as possible.'"

We can now use the above ideas to suggest an instructional 'approach' to cartography that utilizes methods of practice and experience to teach the concept mapping. The method borrows heavily from the understanding of how meaning from language is acquired. We have already explored how acquiring competence in map understanding is similar to acquiring competence in language understanding. Thus, a connection between an instructional approach to language and an instructional approach to mapping is natural. Mapping is no more than map understanding of a percipient. Castner, however, proposes a more formal definition. "Mapping" is the active mental process of thinking about the representation of space, or characteristics which can be ascribed to it, or the arrangement of objects in it,"(1981, p.59). This definition includes

all of the cognitive processes described formerly. Our goal, then, is to pose an instructional 'method' that makes this definition a functional reality. The reality of this situation can be created by application of Neisser's cognitive cycle, known in this work as 'practice.' The instructional methodology is utilized by Shinichi Suzuki and Carl Orff, who are its greatest proponents.

Central to their teaching methods is the concept of improvisation. This appears to be a specialization of practicing. The definition of improvisation is "gradually increasing the number of options and thus the number and type of contrasts and relationships which the student can create and experience" in a particular situation. What improvisation involves, then, is increasing the number of creative options and experiences that a student can have while operating within a series of constraints,

The educators, Suzuki and Orff, have used critical listening and improvisation to teach their students music in the same way children learn to master their native tongue. What is needed here is for the reader to have an understanding that the cognitive processes mentioned earlier apply equally as well to music as they do to language and mapping. This is a very reasonable assumption because the processes themselves are independent of the systems that utilize them. The model is one of thought processing,

not one of independent systems analysis. Once this is realized, then, we do not need to focus on these processes but instead on the cognitive cycle (practice) itself. Let us then consider some practical elements of the teaching 'method.' The elements mentioned are not the products of teaching a specific task, but are those factors which foster an expansion of 'schematic' and 'exploration' potential of the student in the field of music (refer again to Neisser's model).

As the following descriptions of the methods of teaching by Suzuki and Orff are pointed out, keep in mind what good sense they make and also how easily they fit into the cognitive cycle (methods concerned with practicing). Their methods promote practice and experience by creating circumstances that allow the processes of cognition and the cognitive cycle to proceed in a natural way. Put in a simple way, the method consists of fostering a trial and error type of learning. The following discourse about Suzuki and Orff's work is taken from Castner (1981, pp. 59-61).

Dr. Suzuki's method is derived from his own inability or difficulty in learning the German language. It was an obvious fact, but one that much impressed Suzuki, that young children were fluent in their native tongue. He deduced that this was due to the fact that they were sur-

rounded by these sounds from birth. So, he concluded the same parallelism might hold for a child and its ability in music.

Castner mentions that the central aspect to Suzuki's method contains two principles: 1) the child must be helped to develop an ear for music, and 2) from the very beginning, each step must be precisely identified and thoroughly mastered. Practice is necessary, then, to make the principles dynamic forces in learning. The instructor can advocate the first principle through a number of teaching techniques. They include creation of a favorable teaching environment; positive reinforcement for steps achieved; building a repertoire of progressively related pieces in performance; and devotion of much time to just listening. All of these are components of practicing. Also, the child is encouraged to work at his own rate, and the teacher becomes comfortable in letting the child do so. (Muehrcke, 1982, alludes to many of these same techniques in his practical approach to cartography).

Orff's method is not dissimilar to Suzuki's. Orff brings the student in touch with the primal origins of music so that the child can learn to develop a personality in its own right. To this end Orff created a new range of percussion instruments - xylophones, glockenspiels, and metallophones - so that the child could have experience first hand. The medium through which this experience is

gained is improvisation because it acts to stimulate innate qualities of the child. These innate qualities include speech, singing, playing, and movement. If we assume that a basic goal of our educational system is to develop the fundamental perceptual skills of seeing and listening, then methods above may possibly be effective in graphic arts (Castner, 1981).

The question arises, then, as to how graphic arts are being taught today. Currently most instruction occurs in art education. Any worthwhile program will include areas of perceiving, performing, appreciating, and criticizing. However, a distinction needs to be made between this kind of program in art and the same program in music. The distinction is that not all tone combinations are possible or necessarily pleasing in music. The situation thus becomes one of exploiting different tonal possibilities while operating within a series of constraints. These constraints limit the number of communication options that a musical composer has. It is this idea which relates cartography to music education in a closer relationship than art education. Much art does not involve working within a series of communication constraints but is rather an exercise in self-expression. There are no constraints in communication techniques (specifically, no definite method of cognitive

processing) nor are there any rules in interpretation, (no way to generate meaning by applying syntax and semantic rules to fundamental features), in this case. It is not surprising that both Suzuki and Orff have chosen situations where limited options are available for students to experience the relationships and contrasts among these options. Improvisation then becomes a matter of "gradually increasing the number of options and thus the number and type of contrasts and relationships which the student can create and experience" (Castner, 1981, p. 63).

We often see that the range of goals in cartographic education are narrow and of a conventional nature, much as those focusing on such things as scale, symbology, and map projection. (Recall the goals of the researchers in the overview of Chapter I). In the previously mentioned instructional approaches children are introduced to musical "notation" only when they are ready to appreciate the need for it, and it is never posed as an obstacle to be mastered before further progress can be made. Rather it is identified as an auxiliary skill which can be mastered at the same time, but not necessarily at the same rate as performance. Orff exclaims that children must experience music before they are shown how to put it together.

Petchenik (1979, p. 6) states it eloquently when she says:

There is initially an original act of intuition that can be followed by the creation of an intellectual or material product. Reflection, analysis, or criticism can then take place, after intuition-creation. One can attempt to understand how something was done or what something is only after it has come into existence. For example, a poem results from an act of intuition; it is not assembled from rules of grammar and imagery. Once a poem exists, it can be analyzed and modified, but analysis is not the means by which the poem is produced originally.

Even in the realm of map making (as opposed to mapping) there is sentiment that we should be examining the question of map meaning and how maps come to have meaning. That is, map making should have meaning as a basic criterion rather than a visual one (Guelke, 1977). For instance, we realize that what we take for meaning may be elementary. The meaning of a thematic map is derived from the



form of its notation, not the perceptual responses to the mapped phenomenon. Then it will probably be difficult to apply psychophysical approaches of behavioral psychology to more complex questions of cognitive meaning. For example, how can different-looking thematic maps be equivalent in meaning? (Petchenik, 1979, p.11).

Meaning is very illusory, but it is certain that map making and mapping are two separate procedures. A Suzuki or Orff approach would concentrate on practice in mapping. In this approach a limited number of graphic elements can be manipulated such that a variety of useful map products and geographic knowledge may result (improvisation). "Thus, in mapping the type, color, or magnitude of some phenomenon, the various structural dimensions of the symbols (their shape, color, or area) become more significant than their pictorial attributes" (Castner, 1981, p.65).

It is possible to turn now to some practical cartographic concerns that can be used to enhance practice and improvisation in the field. Muehrcke (1982) describes some steps that can be taken to ensure that the Suzuki-Orff instructional approach is successful.

Often, definitions of cartographic terms, including the map itself, provide a guise for value rigidity. Muehrcke poses (pp. 112-16):

Values often constitute self imposed limits which lead to unimaginative resolution of design challenge.... The goal is to generate alternative patterns instead of moving straight ahead with the development of one particular pattern. How, then, does one go about the process of generating alternatives?...First...challenge all assumptions...Nothing should be sacred....Second... suspend judgment. ...The inclination to say 'I know it won't work' should be avoided.

The student's ego is often of practical concern. As early as possible a student should be taught that it is preferable to seek assistance than to guess, which leads to wasting time and materials.

Anxiety is another concern and is often mistaken for laziness. Fear of failure is typical. It can immobilize a student and perpetuate low self-esteem. Positive motivators and encouragement are good remedies.

Boredom and impatience also plague students. Boredom can be handled if routine work can be made into a ritual or is mixed with creative work. Impatience can be checked if students are encouraged to lower their expecta-

tions. They should be as creative as possible while operating under imposed constraints.

Things associated with students' environment often give them problems. Inadequate or improper tools, equipment, and materials are demoralizing for students. Such things lead students to give up in frustration and despair. Bad surroundings, temperature and humidity extremes, poor lighting, awkward furniture all distract from efficient mapping.

These are some practical concerns that cartographic educators should take into their own hands. For example, cartographers can encourage students to learn through practice (improvisation) what pressure to apply to their drafting or scribing tools to obtain the best results. Many tools are ruined by lack of this encouragement. This kind of program will promote a new cartographic approach. The new approach would not destroy the current emphasis of cartographic thought, but would enhance it by promoting practice and improvisation as a way of learning in cartography. The responsibility of implementing such a program must ultimately lie with those cartographers and instructors interested in such an approach.

## CONCLUSIONS

What has just been described are methods of instruction that may enhance our application of "mapping" to cartography. We have not defined the mental constructs that result from engaging the cognitive processes with a specific communication system (whether it be language, music, or cartography). The exact nature of structural similarities among the individual communication systems and the mental constructs derived from them are the subject of further research. However, it is reasonable that the cognitive processes of deriving meaning from these mental constructs are parallel, as was suggested with the analogy between text reading and map reading. We also find that Piaget's theory of stepwise cognitive development and Neisser's cognitive cycle, which we have generalized to the term practice, come to play in deriving meaning from mental constructs. For instance, when Rod Gerber (1984) analyzed children's performance and competence in cartographic language, he found that progressively higher stages of cartographic proficiency were attained as the child aged. Time in the aging process allowed the student to sample objects, thus modifying his schemata, which directed the exploration in the sampling of new objects. This information was compiled into a program that was brought to the map reading task. Reference to the program created mental constructs that provided

cartographic meaning. Representation of that meaning, in cartographic terms, became more sophisticated over time.

It was with all of this in mind that the teaching theory of Suzuki and Orff was introduced. The theory incorporates much of the cognitive aspects of attaining meaning that were mentioned above. The method also focuses on the cycle of cognitive acts. It is suggested, then, that their theory be applied to instructional methods in cartography. After all, cartographic meaning and competence are desirable characteristics in "mapping." If the method is applied to young children, we may see a group of future map users and creators who are proficient in mapping and who do not require remedial training in map reading and interpretation. The enhancement of cartographic education should prove to be well worth the cost of the program's implementation.

#### CHAPTER IV: APPLICATION OF A COGNITIVE MODEL TO COLOR SELECTION IN MAPPING

This chapter is derived from previous work the author did in investigating the use of color in map creation. In it we consider the selection of a color scheme for an isothermal map. Ties to concepts in previous chapters of this paper are made, and focus is turned toward pre-mapping considerations such as color selection. This is the other half of the cartographic process that we must take into account, the former being the mental constructs percipients derive from maps. The two halves are intimately related and are described in the following proposition about color selection.

Charlette Hiatt (1982) has found that cartographers are currently concerned with perceptual investigations of map design as opposed to creating standards within the field and then educating the public. In light of what has been said about mapping as a cognitive process, this seems a most logical enhancement to the current approach of studying cartographic processes. In communication it is not the English language theorists that create the rules by which we understand each other but the needs of humans during standard usage. It is the schemata of individuals, at the time of communication, that establish the rules by which they interpret maps. Therefore, psychological studies of color perception in mapping seem most appropri-

ate as indicators of how cartographers should attack problems of color representation.

The problem that will be focused upon here is the semiological representation of color in mapping and its selection. Psychophysical approaches are warranted because we are concerned with the percipient's response to a visual stimulus. However, cognitive studies are also appropriate because we want to know what the percipient's mental processes are as he responds to color. The two approaches, psychophysical and cognitive meet somewhere in the middle of the spectrum of psychological research, wherein lies the concept of the mental construct. A mental construct is the intellectual product of the process of cognition.

Focus on mental constructs derived from color representation in mapping will aid us in understanding the interface among the map percipient, map product, and map creator. Let us consider an isothermal map. What might be an optimal way of portraying, graphically with color, the variations of temperature across the surface? The first thing that comes to mind is the use of different saturations of the two hues, red to represent hot areas and blue to represent cold areas. Changes in saturation indicate different degrees of magnitude. But, why should this scheme be optimal and effective in representing a

spatial distribution of a natural phenomenon? The focus here is not on the spatial distribution itself but on its portrayal with this particular color scheme. Rudolf Arnheim (1976) offered some answers. He suggests that no detail in a map is closed off from its context. That is, the color of an object is not closed off from its context unless its empirical properties are the reason for consideration, which can only be accomplished in the isolation of, say, a Munsell color chart. The important idea is that details and their context are not separate and distinct. Arnheim also offers,

Colors and shapes must offer spontaneously the qualities that carry the visual answers to the user's questions, and in order to do so, they must have the properties that invite perception. ... Once shapes (colors) can be perceived, they also carry dynamic expression; otherwise they are dead material.

Arnheim goes on to say that what meets the eye first is the expressive qualities carried by the stimulus data. What we actually hear Arnheim saying is that meaning of any color or shape is determined from the cognitive processes of feature detection, recognition, and rehearsal and recoding utilized through 'chunking.' Application of



Neisser's cognitive cycle to this cognitive model is the means for generation of mental constructs regarding the symbolization of color. Employing Neisser's cycle continuously over a period of time produces experience. It is our experiences with certain colors that influence our expectations of the where, when, why, and how of their occurrence. That is, exploration of an object modifies our schemata, which directs exploration, etc. For example, because of our experiences we expect fire, hot stove burners, blood, etc., to be red, while we expect ice, ocean depths, etc., to appear blue. Therefore, when we hear the words hot and cold, the first color associations that come to our minds are red and blue, respectively, not purple and yellow, green and orange, or any other color combination. One may wonder why we may not create the inverse situation, where red is cold and blue is hot, by assigning meaning through a legend. It seems that experience is dominant in this case.

We can refer to a study on the visual intolerance of ambiguity replicated by Thomas Strand Ball (1955) . Ball found that when presented with visual ambiguities, subjects strived to create a harmonious or coherent state to explain away the ambiguity. This is known as the visual intolerance of ambiguity, which is measurable, and was first introduced by Frenkel-Brunswik (1949). It cannot be denied that the measured intolerance

is a variable of personality, which is a function of individual needs and motives. However, the color associations of red and blue to hot and cold are almost universally accepted in the civilized world. Experience, gained through cognition, rules here. Therefore, when a subject is presented an isothermal map in which the legend reads that blue stands for hot and red stands for cold, it is not as effective as the reversed color scheme would be. The subject's mind would perceive an ambiguity and would strive to put things in their "correct order" based on a myriad of past experiences. Thus, the perceived ambiguity would be resolved and a state of equilibrium would return to the perceptual framework. This equilibrium is analogous to the equilibrium obtained by adaptation (accommodation and assimilation) in Piaget's human development model.

Formerly, it was mentioned that the first thing one notices about a map is the expressive qualities of the stimulus data. In a review of the psychological literature dealing with color in mapping, Mary Monschein (1981) noted that color preferences may be relevant to the cartographer. It is true that color preference is a variable of personality, as is visual intolerance, and differs among cultures, ages, and individuals. It is a variable that deals with aesthetic value, which deals less with certainty than any other personality variables. Concerning

certainty A. Kirschmann (19??) writes,

nothing is absolutely certain unless  
it consists of ... assertive and apo-  
deictic (sic) elementary facts or can  
be derived from them by means of  
application of the apodeictic (sic)  
facts.

For example, the quality red cannot be 'defined.' No matter how complicated its designation or expression, it is absolutely and ultimately simple. It is apodictic, or incontestable, an elementary building block and is therefore certain. The aesthetic value of the color red, on the other hand is uncertain. To tie this in with Monschein and color preference then, it seems ill-advised for a cartographer to choose a color scheme based on color preference and the aesthetic because of this business of uncertainty of the whole matter. It seems that experience would be a better criterion for choosing the scheme because it is more certain and universal. Thus, we conceive an isothermal map that has gradations of red to represent warmth and gradations of blue to represent coolness. It does not have to 'catch' our attention by appealing to our color preference before it transmits information. The converse is true. The map transmits information through the colors chosen to represent the attribute data.

We can summarize what has been mentioned about color selection by stating that cognitive aspects of the map creation and design process should not be disregarded. Experience serves well as a base for color selection when apodictic building blocks can be derived from it. Apodictic building blocks serve as the basis of universal experience, then mental constructs that are similar are produced in percipients. Thus, most everyone would agree that choosing red for hot and blue for cold in the isothermal map is the most logical and familiar choice.

## CONCLUSIONS

It was suggested that in the case of the isothermal map a good criterion for selection of a color scheme may be experience. The more universal the experience, the better. Map creators may benefit by exploring the nature of 'universal' experiences and noting their common attributes, which may be applied to the area of semiotics. As many of the relationships among the attributes as possible should be examined. The method of improvisation proposed by Suzuki and Orff would be a powerful tool in accomplishing this task. <

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